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UNITED STATES DISTRICT COURT
CENTRAL DISTRICT OF CALIFORNIA

KEITH ANDREWS, an individual, TIFFANI ANDREWS, an individual. BACIU FAMILY LLC, a California limited liability company, ROBERT BOYDSTON, an individual. CAPTAIN JACK'S SANTA BARBARA TOURS, LLC, a California limited liability company, MORGAN CASTAGNOLA, an individual, THE EAGLE FLEET. LLC., a California limited liability company, ZACHARY FRAZIER, an individual, MIKE GANDALL, an individual, ALEXANDRA B. GEREMIA, as Trustee for the Alexandra Geremia Family Trust dated 8/5/1998, JIM GUELKER, an individual, JACQUES HABRA, an	**Case No. 2:15-cv-04113-PSG-JEM** [Consolidated with Case Nos. 2:15-CV- 04573 PSG (JEMx), 2:15-CV-4759 PSG (JEMx), 2:15-CV-4989 PSG (JEMx), 2:15-CV-05118 PSG (JEMx), 2:15-CV- 07051- PSG (JEMx)] **EXPERT REPORT OF IGOR MEZIĆ, Ph.D.**

individual, ISURF, LLC, a California limited liability company, MARK KIRKHART, an individual, MARY KIRKHART, an individual, RICHARD LILYGREN, an individual, HWA HONG MUH, an individual, OCEAN ANGEL IV, LLC, a California limited liability company, PACIFIC RIM FISHERIES. INC, a California corporation, SARAH RATHBONE, an individual, COMMUNITY SEAFOOD LLC, a California limited liability company, SANTA BARBARA UNI, INC., a California corporation, SOUTHERN CAL SEAFOOD, INC., a California corporation, TRACTIDE MARINE CORP., a California corporation, WEI INTERNATIONAL TRADING INC., a California corporation and STEPHEN WILSON, an individual, individually and on behalf of others similarly situated,

Plaintiffs,

v.

PLAINS ALL AMERICAN PIPELINE, L.P., a Delaware limited partnership, PLAINS PIPELINE, L.P., a Texas limited partnership, and JOHN DOES 1 through 10,

Defendants.

EXPERT REPORT OF IGOR MEZIĆ, Ph.D.

1. I am a co-founder and Chief Technology Advisor of AIMdyn, Inc. I am also a Professor at the University of California, Santa Barbara and a Fellow of the American Physical Society, the premier organization of researchers in physical sciences, and the Society for Industrial and Applied Mathematics, the premier organization of researchers in Applied Mathematics. My research focuses on identifying key physical phenomena in a complex device or a natural system, and using that information to create forecasts or design new concepts on which devices can be built or improved.

2. For example, complex natural phenomena such as dispersion of oil on and below the ocean surface involve a large set of physical phenomena. Nonetheless, accurate predictions of where oil will flow can be made by identifying the key indicators (phenomena) that impact the flow and then computing where they will direct the flow. Such indicators and associated algorithms exist for a number of complex physical processes that involve mixing, including oil spills, jet engine instabilities and building energy efficiency indicators. As a result of my work in this area of research, the American Physical Society elected me as a Fellow for my "fundamental contributions to the theory of three-dimensional chaotic advection, measures and control of mixing, and development of a spectral operator theory approach to decomposition of complex fluid flows." In addition, the Society for Applied and Industrial Mathematics elected me as a Fellow for "sustained innovation at the dynamical systems theory/applications interface; notably for advances in the use of Koopman operator theory.

ASSIGNMENT

3. Plaintiffs in this action retained my services to develop an analysis to determine, to a reasonable degree of scientific certainty, where the oil from the Line 901 spill flowed in the ocean, including: (1) what geographic area it covered; (2) where it became submerged; (3) where it washed ashore, including duration and

volume; (4) the extent to which submerged oil reemerged onto the surface areas of the ocean; and (5) the duration and volume of oil in fishing blocks.

4. In my first two declarations (Declaration of Igor Mezic, Ph.D., in Support of Plaintiffs' Motion for Class Certification [Dkt. 128], and Rebuttal Declaration of Igor Mezic, Ph.D. [Dkt. 216]), I explained how I could develop such an analysis, provided background on how oil "moves" in oceans, and presented the results of my preliminary analysis.[1]

5. After the February 27, 2017 hearing, Plaintiffs asked that I determine, to a reasonable degree of scientific certainty, where the oil from the Line 901 spill flowed in the ocean, including some of the above parameters. That work was presented in my third and fourth declarations [Dkt. 300-4 and Dkt. 399.].[2]

6. After the April 17, 2017 Order Plaintiffs asked that I complete my work on: 1) analysis of the effects of cleaning procedures on the results of the simulation; 2) duration of oil concentration of different levels on the shoreline, divided by individual housing parcels on the shoreline; 3) analysis on the mass of oil present in individual fishing blocks over time; 4) model-based analysis of natural seeps in the area affected by the Line 901 oil spill and study of the effect of such natural seeps on prior conclusions; 5) analysis of oil presence above the mean high tide line; and 6) analysis of bounds on the amount of oil reaching the ocean.

7. My company, Aimdyn is being compensated $350/hour for my work on this assignment.

PROFESSIONAL BACKGROUND

8. My research and teaching over the past twenty-eight years intersect the fields of fluid mechanics and mathematics. My undergraduate degree is in

[1] Defendants filed a motion to strike my first declaration, but the Court denied that motion. (Order GRANTING IN PART and DENYING IN PART Plaintiffs' Motion for Class Certification, and DENYING Motions to Strike [Dkt. #257], pp. 9 and 13.)
[2] Defendants filed a motion to strike my third declaration, but the Court denied that motion. (Order GRANTING Plaintiffs' renewed motion for class certification and DENYING Defendants' Motion to Strike [Dkt. #454], pp. 5-8.)

Mechanical Engineering, with emphasis on Thermal and Fluids Engineering. I received a Doctor of Philosophy (Ph.D.) from the California Institute of Technology ("Caltech"), within the Applied Mechanics Program, based on my Thesis entitled "On Geometrical and Statistical Properties of Dynamical Systems: Theory and Applications." In my thesis, among other contributions, I developed a methodology to study kinematics of three-dimensional fluid flows, and published it in the paper Mezić, I., and Stephen Wiggins. "On the integrability and perturbation of three-dimensional fluid flows with symmetry." *Journal of Nonlinear Science* 4 .1 (1994): 157-194. This led to a series of research papers on three-dimensional motion of fluid particles and fluid mixtures, such as dye-water mixtures. I was credited with the development of this theory when I was inducted into the Fellowship of the American Physical Society, and based part of my analysis of advective and diffusive effects of the Line 901 spill on developments that followed from it.

9. I was a postdoctoral fellow at the Mathematics Institute of the University of Warwick in the United Kingdom in 1994-1995. Beginning in 1995, I was an Assistant Professor at the University of California, Santa Barbara ("UCSB") and I started a Nonlinear Dynamics research group at UCSB in 1995.

10. From 2000-2001, I was an Associate Professor at Harvard University. During that time I researched and then published one of the most cited papers on mixing in the history of the subject, in the prestigious journal *Science*. (Stroock, A. D., Dertinger, S. K., Ajdari, A., Mezić, I., Stone, H. A., & Whitesides, G. M., "Chaotic Mixer For Microchannels," *Science* 295, 647-651 (2002).) This paper was subject to strict peer review prior to publication, and involved a number of the issues related to my analysis in this case.

11. I returned to UCSB and became a Full Professor there in 2003. In 2006, I co-founded the Institute for Energy Efficiency at UCSB, where I still serve

as the Head of Buildings and Design Group and Director of the Center for Energy Efficient Design.

12. I have received awards in three different scientific disciplines: automatic control; mathematics and dynamical systems theory; and technology development based on basic science. Among other awards, I was the recipient of the prestigious Sloan Fellowship in Mathematics in 1999. For my work on technology related to jet engines produced by Pratt and Whitney, I was awarded the United Technologies Senior Vice President's Special Award in 2007. My research and work involved a combination of fluid flow processes of complexity similar to the problem that is considered here. I was inducted to be a Fellow of the American Physical Society in 2016 and a Fellow of the Society for Industrial and Applied Mathematics in 2017. I also have given a number of Plenary and Keynote lectures at conferences in Asia, Europe and the Americas on subjects similar to those discussed in this report.

13. I am a co-Founder of three companies that produce software and hardware related to flow processes: Aimdyn, iFluidics and Ecorithm. Aimdyn, Inc. was established in 2003 to develop powerful forecasting technologies for broad use in industry. Amongst its customers and collaborators are large corporations such as United Technologies, Ford and Cummins; researchers at prominent universities such as Princeton University; as well as preeminent national research agencies such as DARPA (Defense Advanced Research Project Agency) and NIH (the National Institutes of Health). Aimdyn has developed a suite of software tools that enable users to forecast and propose best remedial or control action for engineered or natural systems. Aimdyn has a depth of expertise in flow mechanics, mechanical engineering, automatic control, vehicle terrain or ocean coverage and cleanup strategies and has developed proprietary software in each of these fields.

14. Many of the methods applicable to my analysis of where the oil flowed after entering the ocean relate to the topics described above, which I have been researching and applying for the past 28 years.

15. This is the only matter in which I have provided expert testimony in the last four years.

16. A copy of my CV is attached as Exhibit A.

PREDICTING THE FLOW OF OIL IN THE OCEAN

17. As noted above and in my prior declarations, years before the Deepwater Horizon oil spill, I developed an algorithm that I believed could be used to more accurately predict where the oil would flow in situations like that which ended up occurring in the Deepwater Horizon spill. That algorithm had been presented – to positive reviews – in lectures at the California Institute of Technology and the École Normale Supérieure in Paris.

18. After the Deepwater Horizon oil spill, and based on information available during that oil spill, I ran calculations through my algorithm and plotted where the oil would likely flow. Satellite observations of the oil slick confirmed the accuracy of my analysis.

19. The type of modeling that led to accurate prediction of oil distribution during the Deepwater Horizon oil spill has been subjected to a high degree of scrutiny. The analysis and modeling underwent strict peer review and then was published in the journal *Science* in 2010. (Mezić, Igor, et al., "A New Mixing Diagnostic and Gulf Oil Spill Movement," *Science* 330, 486-489 (2010).) The publication of the analysis in *Science* attracted the attention of the scientific community. According to Google Scholar, the work has been cited more than 150 times since its publication.

20. The analysis was expanded by looking at the behavior of the microbiological populations in the Gulf and their behavior during and after the Deepwater Horizon oil spill. The expanded work was invited for publication, and

then published, in the *Proceedings of the National Academy of Sciences* by the then Administrator of NOAA and Under Secretary of Commerce for Oceans and Atmosphere, Dr. Jane Lubchenco. (Valentine, D., Mezić, I., Macesic, S., et al., "Dynamic Autoinoculation and the Microbial Ecology of a Deep Water Hydrocarbon Irruption," *Proceedings of the National Academy of Sciences* 109, 20286-20291 (2012).) This article also was subject to rigorous peer review. The article concluded that the analysis – performed using an ocean model – accounted for 80-90% of observed data within a kilometer range.

21. The analysis has been tested, subjected to peer review, published and is generally accepted in the scientific community. The analysis predicts, to reasonable degree of scientific certainty, the pathways of oil flowing from a spill site. The location of predicted pathways can be compared with the location of the observations from overflight data, satellite data, microbiological tests and shoreline samples, when such observations exist. Strict standards for processing of data are utilized when applying the methodology, the most important ones being the time and space resolution standards. The acceptance of the methodology in the scientific community is broad, with hundreds of papers citing its relevance for prediction of properties of mixing processes and oil spills.

22. A key component of this model is that it is able to derive the key flow structures in the ocean that impact the distribution of oil during and after a spill. These structures are not uniform in space, and produce what is known as an “effective diffusivity” that depends on non-uniform flow structures. This, in turn, is referred to as the spatial dependence of effective diffusivity.

23. By way of example, and speaking in simplified terms, ocean flows have three primary types of structures that can carry oil. Each impacts oil differently. (1) Eddies are rotational, relatively slow mixing zones. Oil will either not enter these zones or will enter them slowly and then rotate within the confined area of the eddy until the eddy, or a portion of the eddy, becomes a different

structure. (2) Shear regions move linearly in one spatial direction at a time and can change direction multiple times over the course of the day. Oil readily enters these regions, is stretched, and generally moves in the direction the shear region is moving. When the shear region's direction changes back and forth, the oil effectively sloshes back and forth. (3) Mixing zones are regions where rotational and shear motion is combined to produce a mixture over a surface area. In these zones, oil is repeatedly stretched and then folded back on itself, similar to how hand-pulled noodles are made.

24. Returning to the concept of the spatial dependence of effective diffusivity, the oil is pushed or pulled (effective diffusivity) differently based on where and when it encounters each structure (spatial dependence).

25. Eddies, shear regions, and mixing zones can be identified based on velocity – the rate at which positions in the ocean change. Information on velocity is readily available, either through actual data from high frequency radar measurements or through computed data.

26. The approach to calculating distinguished structures that are responsible for dispersion in ocean flows relies on following oil-carrying fluid volume tracks over a finite period of time corresponding to the period over which a prediction is required. For this, the velocity field v of the ocean is needed as an input. This is supplied either by a numerical model (as was the case during the Deepwater Horizon oil spill) or measured velocities (as was the case during the Refugio Line 901 oil spill).

27. Once you have the velocity field, you compute its average over particle tracks over a finite period, and call it v*, the average Lagrangian velocity. This quantity depends on the initial position of the oil particles and the time period over which it is computed.

28. The crucial step comes next: You compute the difference in average Lagrangian velocities that nearby oil particles experience. That difference is

labeled $\nabla \mathbf{v}^*$. This is a matrix that depends on initial conditions and the time-period T. You then categorize the different regions by the values of the determinant of that matrix, $\det \nabla \mathbf{v}^*$. The negative values of this quantity correspond to rotation with strain of nearby particles, and are presented graphically in red. The positive values, less than $4/T^2$, represent elliptic, quiescent regions and are labeled green or white. The positive values, larger than $4/T^2$, represent hyperbolic behavior and are shown in figures by blue color.

29. Streaks of red and blue next to each other can be interpreted as shear zones, where the distribution of oil gets stretched along in the direction of the streak. Green zones can be interpreted as the regions where the motion of the oil does not produce much deformation in the shape of its spatial distributions. Zones with intricate mixtures of red and blue can be interpreted as mixing areas where the oil is spread over a substantial portion of the affected field. These structures are jointly called hypergraph structures.

30. Once the distribution of these structures at different points in time are identified, other relevant data is incorporated to determine to a reasonable degree of scientific certainty where the oil is going to flow. For example, wind effects and evaporation effects can be included using appropriate modeling tools, as described below.

THE PRELIMINARY HYPERGRAPH ANALYSIS

31. A hypergraph analysis was performed to validate the accuracy of the velocity field. This analysis considered the flow structures in the relevant area over 30 days following the spill. This was the first step of my analysis. Actual oil sightings confirm the validity of this analysis.

32. Based on the scientific method I employed, the scrutiny applied to that method, and real-world confirmation through oil sightings, I conclude that the velocity field accuracy is sufficient to identify, using additional analysis, the geographic area the oil covered to a reasonable degree of scientific certainty.

THE ANALYSIS OF THE LINE 901 SPILL

33. Because I have obtained daily velocity data and other relevant information, I have determined to a reasonable degree of scientific certainty what happened to the oil between the time of the Line 901 spill through the present.

34. The analysis took the following approach:

- Velocity data was obtained from high frequency radar measurements. An example of the velocity field so obtained is shown in Ex. C of my first declaration [Dkt. #128-3]. This serves as the previously described velocity field v.
- The initial distribution of oil in the near-shore region was determined.
- Wind data was incorporated into the analysis through industry-accepted methodologies and its effect on the distribution evaluated.
- Evaporation data was incorporated into the analysis and its effect on the distribution evaluated. This is a basic formula that has broad industry acceptance.
- To confirm the validity of the analysis, the results of the analysis were compared to available data on where oil was actually identified. This included the NOAA flyover data and SCAT data regarding oil located on shore.
- Cleanup information was incorporated into the model to address the effect of the cleaning activity on the maximal concentration and duration of the oil presence on the shoreline at different concentration levels and individual impacted parcels.
- Probability of distribution of oil above and below mean high tide line was determined using a generally accepted approach.
- Distribution of oil was determined for individual fishing blocks by aggregating information from spatial distribution of oil within each individual block. The video of evolution of oil concentration in fishing

blocks and the raw data in Excel database format accompany this report in their respective native formats.[3]

- Determination of the impact of seeps on the oil distribution was performed using literature-based data on typical oil seep parameters in the Santa Barbara Channel.
- Determination of the most likely amount of oil that reached the sea was done using an optimization procedure.

35. Using this approach, I was able to provide an hour-by-hour analysis, allowing me to determine to a reasonable degree of scientific certainty where (and when) the oil travelled, became submerged, and washed ashore, and the extent to which unbeached oil has reappeared on the shoreline. It also allowed me to determine the effects (if any) of cleaning procedures and natural seeps on the distribution and duration of oil present on the shoreline and in the ocean. The additional analysis sharpened the statement on the amount of oil that reached the ocean.

A. Lagrangian Oil Transport Model

36. We use the Lagrangian formulation of oil spill transport. The spill is represented as a collection of discrete particles which are affected by vector fields (flow fields, validated using the technique described above) governing their movement. The ocean current velocity fields were acquired from HF Radar measurements at 2 km spatial resolution and 1 hour temporal resolution, while the wind velocity fields at 10 meters above sea level were acquired from COAMPS data servers for 3 hour temporal resolution and 4 km spatial resolution. Both fields were linearly interpolated at the required location (be it particle locations or the center of the oil slick). The surface particles were affected by the current velocity

[3] See "fisheries_impact.mp4; fishing_blocks_8000bbl.xlsx; fishing_impact_10750bbl.xlsx"

field, the wind velocity field and turbulent diffusivity terms, while oil particles dispersed under the surface were not affected by the wind velocity field.

37. The particle moving through the fluid undergoes Brownian motion, due to the action of incoherent turbulent motions. This process is described with an effective diffusivity coefficient which governs the random walk motion of the particle at each given time step.

38. The model simulates particle beaching and unbeaching. If the particle is about to enter the simulation cell situated on the shoreline, the particle status is set as beached. The beaching of a particle may not be permanent. At subsequent time steps there is a probability that the particle may be washed back into the water.

39. The model takes into account the cleaning data (see paragraph 43, below).

B. Oil Fate Model

40. The changes of the surface oil volume are attributable to processes known collectively as weathering. These include evaporation in which the lighter fractions of oil evaporate. Oil particles can be dispersed below the water surface. A surface spill spreads mechanically over the water surface under the action of gravitational forces. The model incorporates emulsification, the mixing of the water with the oil. The weathering processes are considered separately for the zones of thick and thin slick (or sheen).

41. In order to solve for the advection–diffusion processes, and compute surface oil volume concentration, dispersed oil volume concentration and beached oil volume concentration, we define the particle state variables. The initial surface volume is broken into constituent particles that are characterized by a particle volume, by a particle status index (representing whether the particle is surfaced,

dispersed or beached) and by a position vector. A numerical grid is specified where we can count particles and compute the appropriate volumetric concentration.[4]

C. Windage and Diffusion Coefficient Optimization

42. To determine the diffusion coefficient for random walk transport term as well as the windage coefficient which determines the percentage of wind velocity affecting the movement of the oil slick, an optimization analysis was performed using available data.

D. Effect of Cleaning Procedures

43. The cleanup information was obtained from cleanup surveys. The uniformly discretized shoreline points are each assigned a SCAT segment ID. These are cross-referenced with the available cleanup data based on the last conducted survey. This data contains the status of the segment cleanup (whether the process is still active) and the date of the survey. During the simulation a radius is checked around a shoreline point during the day stated in the data and then any arriving particle in that radius is removed from the simulation. The assumed cleanup time is daily between 0800 and 1700 hours. Total volume is updated by subtracting a percentage based on the relative number of removed particles. The duration of oil on the shoreline was calculated taking into account the cleaning procedures.[5]

E. Oiling in Fishing Blocks

44. The numerical analysis of the concentration of oil in the ocean provides the mass of oil in volume near the surface. From that mass we calculated the mass of oil in fishing blocks provided to us. The calculation consisted of aggregation of the mass over the fishing block. The mixing processes near the surface ensure that every portion of subsurface ocean volume is exposed to the

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[4]Oil Fate Model source code, compiled application and source data previously produced as PLTF-EXPT-IM-0000262-263.

[5] See PLAINS-CL00195083; PLAINS-USCG-0284200

surface oil concentration. However, to provide a conservative estimate of the maximum exposure, we assumed that oil was distributed over the layer of ocean 1 meter below the surface, in kg/m^3[6]. This was converted to parts per million by other experts for use in toxicity estimates.

F. Duration and Amount of Oiling On The Shoreline

45. The model of oil fate and transport that we developed includes the full model of transport of oil on and below the surface, as well as the processes of beaching and unbeaching of oil particles. The beach segments identified in this analysis were modeled to determine the maximum level of oiling on each beach segment. We then identified beach segments that were oiled at a level "Light" or above.[7] The oiling on the beach segments identified in this analysis was further modeled to determine the total duration any of the identified beach segments was oiled at a level Light or above.[8] Each beach segment then was subdivided by property boundaries, which yielded the duration each impacted property was oiled at a level Light or above.

46. The property "segment file" containing geographical coordinates of individual property segments as well as other identifying data is preprocessed by calculating the midpoints of the segments themselves.[9] These are used as referent concentration points for the property segments. The actual concentrations are calculated by scanning a radius around each particular shoreline point for beached Lagrangian particles (which carry the oil volume and are transported by the surface currents) and then projecting that value on the length of the segment which is

[6] "fishing_blocks_8000bbl.xlsx; fishing_impact_10750bbl.xlsx"

[7] Categories of oiling are derived from the NOAA Shoreline Assessment Manual, 4th Edition and include: Heavy, Medium, Light, Very Light or No Oil Observed (NOO) (previously produced as PLTF-EXPT-RB-0002857-3010.)

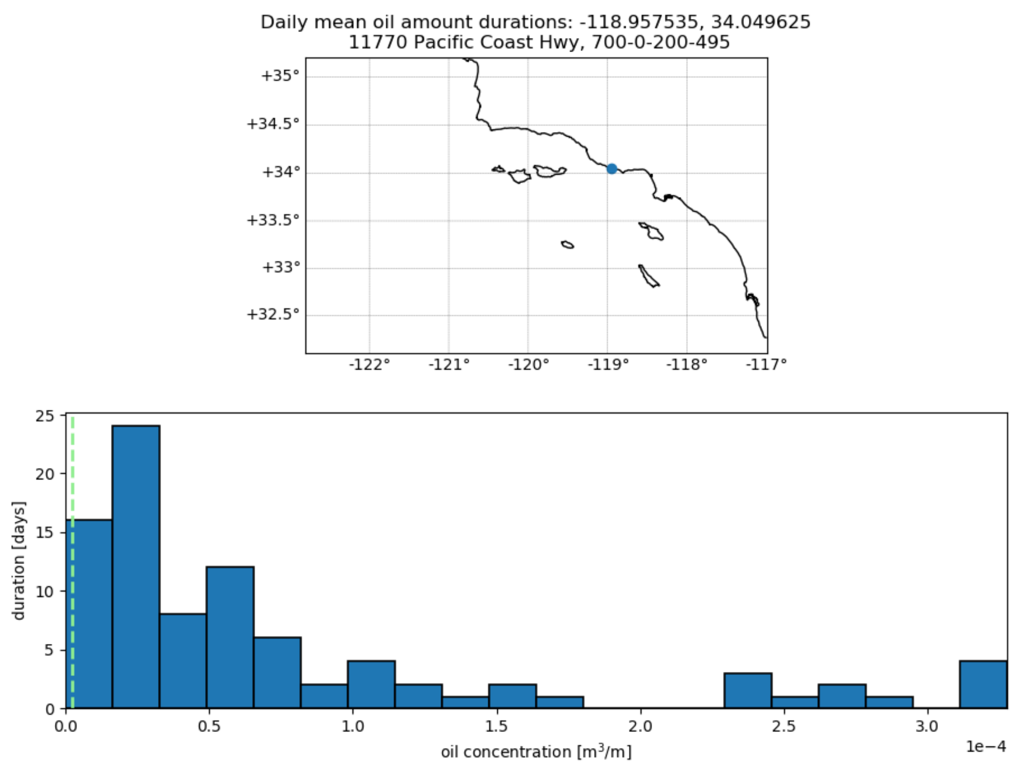
[8] The fate, cleaning and unbeaching processes ultimately lead to the Very Light or No Oil Observed state, pursuant to SCAT categories adjusted for no overlap.

[9] "040 Plains Oil Los Angeles excluding Long Beach.xlsx; Santa Barbara and Ventura.xlsx"

represented by that shoreline point to get a concentration value in a volume over length measure.

47. The concentration results are calculated with a 15-minute resolution, so an average value is used to set a daily concentration value for each segment. The concentration values for each point in each day are summed and then divided by the number of 15-minute timesteps in a day. These daily values are then categorized into concentration bins which results in day counts of average oil concentration for each segment, on a range between the minimum and maximum concentration values for that segment across the duration of the entire simulation.

48. The figure below shows the location and duration of oil concentration levels for the location indicated in the figure. Such calculations have been performed for every impacted property, and accompany this report in native format.[10] The duration of oiling at Light or above on the impacted parcels was as long as 86 days.



[10] “oil_durations.xlsx; property_durations.dbg; property_durations.shp; property_durations.shx”

G. Oil Above Mean High Tide Line

49. An evaluation of the probability distribution of oil along the shoreline was performed to determine whether oil reached the high tide line. The assumption of the Gaussian probability distribution for which the mean is set up using the SCAT manual information (NOAA Shoreline Assessment Manual, 4th edition) confirms that in most cases the amount of oil deposited above the high tide line was above 50% of all the oil present at that location, and in all cases the amount of oil above the high tide line was substantial.

H. Impact of Oil Seeps

50. The simulation software is capable of performing a simulation of several discrete oil seeps with different source locations. The total number of Lagrangian particles that carry the oil volume are uniformly distributed among 6 natural oil seeps and the locations of these seeps are set based on the available data. Each seep is treated as a continuous release of volume per timestep based on the total volume spilled from all seeps during a ten-day period, to cover the initial 10-day period of the Refugio Line 901 spill. The particles are released based on a spatial Gaussian distribution with the center being the seep location and the spread of 150 meters. The particles released are considered to have floated to the surface after release. Each seep fate is updated independently. Aside from the introduction of seeps, the simulation is run as the simulation of the Line 901 spill.

51. The results of this simulation, with a variety of initial volumes, confirm that the profile of the oil distributed on the shoreline resulting from the natural seeps is drastically different than the profile of oil concentration calculated from SCAT team observations. Even with the highest observed volume seep release of 600 bbl/day simulated over 10 days, the shoreline concentrations are 2-5 orders of magnitude lower than oil concentration calculated from SCAT team observations. This proves that natural seeps do not change the conclusions from the previously conducted study.

52. Videos showing the evolution of the shoreline concentration from natural seeps have been generated and accompany this report in native format.[11] Videos showing the evolution of comparisons between SCAT team observations and natural seeps have also been generated, and accompany this report in native format.[12]

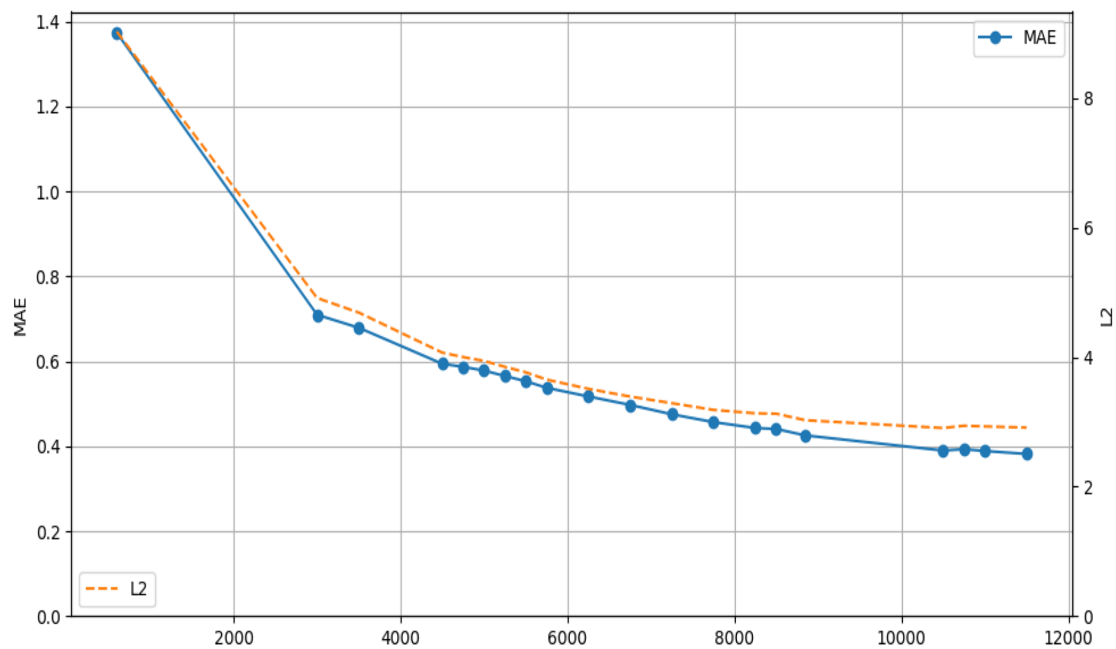
I. Estimated Volume of The Spill in The Ocean

53. According to the Final Report US Coast Guard, Order No. 2015 01-FPN A15017, prepared by Plains and its consultants, Plains estimated that Line 901 oil recovered from the ocean is 311 bbl. This is more than 50% of the 598 bbl that Plains estimated to have reached the ocean. However, according to the Office of Technology Assessment of the Congress of the United States, historically cleaning procedures show "The rapid spreading and fragmentation of oil that occurs after a spill has made cleanup of large percentages of oil exceedingly difficult. Historically, recovery from major spills has amounted to only a few percent . . ." It is highly probable that the Line 901 oil spill was no different. Our estimates of the oil volume spilled to the ocean from the Line 901 spill lead to the conclusion that the recovered amount was no larger than 2-3%, in accordance with the referenced OTA Assessment.

54. We have performed an additional optimization procedure to sharpen the bounds on the estimated volume of oil spilled into the ocean. The optimization included comparing output of numerous simulations with different initial oil volumes with the concentration data from SCAT observations. This means that we have optimized the output of the model taking into account the uncertainty of the SCAT observations near the spill site where the collection was most accurate. The results are as follows: The most probable volume of oil in the ocean was 10,750

[11] See "particle_transport.mp4; surface_volume.mp4", generated at 100, 300 and 600 bbl/day seep volume.
[12] "shoreline_concentrations_vs_max_scat.mp4", generated at 100, 300 and 600 bbl/day seep volume.

bbl. The range of possible volumes is between 8,000 and 11,500 bbl. This is clearly seen from the figure below. Firstly, the curve describing the difference between the model and the data monotonically decreases starting with an initial volume of 600 bbl. The curve clearly starts leveling off with the increase of oil volume at 8,000 bbl, and is a minimum as the most probable oil volume. These estimates are consistent with an upper bound that I provided in my previous declaration, based on the difference of oil concentration observed at Coal Oil Point and its maximal historical concentration.



CONCLUSIONS

55. The result of the incorporation of the cleaning data did not change the results of the previous analysis, as the analysis was based on the maxima of the concentration on the shoreline.

56. The new analysis of the impact of natural seeps confirmed that natural seeps did not have an effect on the conclusions of the previous studies.

57. New results that aggregated previous information on the concentration of oil in the ocean in fishing blocks were obtained.

58. The analysis of the duration of oil concentration of various levels on the shoreline was performed. The results were aggregated to show duration of oiling above Light on the shoreline.

59. We estimated the volume of the spill by comparing the concentration of oil obtained from the model, initiated with various initial volumes, with the SCAT data. We performed an optimization procedure that provided the upper and lower bound on the volume of oil in the ocean. The lower bound is 8,000 bbl and the upper bound is 11,500 bbl. The most probable volume is 10,750 bbl.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed on March 29, 2019, in Santa Barbara, California.

Igor Mezić, PhD

EXHIBIT A

Curriculum Vitae

October 2016.

Name: IGOR MEZIĆ

Positions held:

- *2008 - present:* Professor and Director, *Center for Energy-Efficient Design* and Head, *Buildings and Design Solutions Group of the Institute for Energy Efficiency*, University of California, Santa Barbara, USA.
- *2001-2010* Associate Professor and Professor, *Department of Mechanical Engineering*, University of California, Santa Barbara, USA.
- *January 2000 - August 2001*: Associate Professor, *Division of Engineering and Applied Science*, Harvard University, Cambridge, USA.
- *1995 -2000* Assistant Professor and Associate Professor, *Department of Mechanical Engineering*, University of California, Santa Barbara, USA.
- *June 1994 - June 1995*: Postdoctoral Research Fellow, *Mathematics Institute*, University of Warwick, UK.

Education:

- Ph.D. in *Applied Mechanics*, California Institute of Technology, Pasadena, CA, USA. (1994). Thesis advisor: Professor Stephen Wiggins.
  Thesis: "On Geometrical and Statistical Properties of Dynamical Systems: Theory and Applications".
- Dipl. Ing. in *Mechanical Engineering*, Technical School of Rijeka (TSR), University of Rijeka, Croatia. (1990) Thesis advisors: Professor Luka Sopta and Professor Zoran Mrša.
  Senior Thesis: "On Numerical Solution of Viscous Fluid Flow Using the Finite Elements Method".

Selected honors and awards:

- National Science Foundation CAREER Award for research on *"Nonlinear Dynamics and Control from Microscale to Macroscale"* (1999).
- Sloan Fellowship in *Mathematics* (1999).
- Axelby Outstanding Paper Award (IEEE Transactions on Automatic Control) for the paper on *"Control of Mixing: a Maximum Entropy Approach"* (2000).
- Invited Plenary Lecturer, *Dynamics Days Europe,* Palma de Mallorca, Spain (2003).

- Invited Plenary Lecturer, *SIAM Control Theory Meeting*, New Orleans, USA (2005).
- Invited Plenary Lecturer, *The Second International Conference on Dynamics,Vibration and Control,* Beijing, China (2006).
- Opening Lecturer, *First Lab on a Chip World Congress,* Edinburgh, Scotland (2007).
- United Technologies Senior Vice President's Special Award (2007)
- Invited Plenary Lecturer, *SIAM Conference on Applications of Dynamical Systems,* Snowbird, Utah (2009).
- Project on Dynamic Network Analysis for Network Uncertainty Management selected as one of the top AFOSR-sponsored projects in its 60 years of existence (2013)
- Invited Plenary Lecturer, *Control of PDE's* Paris (2014).
- Fellow of the American Physical Society (2015)
- Fellow of the Society for Industrial and Applied Mathematics (2017)

Current research interests:

- Operator theoretic methods in dynamical systems.
- Science and technology of dynamics of energy efficiency; including building systems and power grids.
- Mixing and separation in fluids across the scales with applications ranging from microfluidic phenomena to oceanographic flows.
- Nano and micro-scale particle dynamics induced by dielectrophoresis and other electrokinetic phenomena, with applications to biotechnology.

Journal articles:

1. I. Mezić and S. Wiggins, "On the integrability and perturbations of three-dimensional fluid flows with symmetry". *Journal of Nonlinear Science* **4**, 157-194 (1994).
2. I. Mezić and S. Wiggins, "On the dynamical origin of asymptotic t^2 dispersion of a non-diffusive tracer in incompressible laminar flows". *Physics of Fluids*, **6**, 2227-2229 (1994).
3. I. Mezić and S. Wiggins, "Nonergodicity, accelerator modes, and asymptotic quadratic-in-time diffusion in a class of volume-preserving maps". *Physical Review E*, **52**, 3215-3217 (1995).
4. I. Mezić, J. F. Brady and S. Wiggins,"Maximal effective diffusivity for time periodic incompressible fluid flows". *SIAM Journal of Applied Mathematics*, **56**, 40-56 (1996).
5. I. Min, I. Mezić and A. Leonard, "Lévy stable distributions for velocity and velocity difference in systems of vortex elements". *Physics of Fluids*, **8**, 1169-1180 (1996).
6. I. Mezić, "FKG inequalities in cellular automata and coupled map lattices." *Physica D*, **103**, 491-504 (1997).

7. M.J. Keeling, I. Mezić, R. Hendry, J. McGlade, and D.A. Rand, "Characteristic length scales of spatial models in ecology via fluctuation analysis". *Philosophical Transactions of the Royal Society*, **B 352**, 1589-1601 (1997).

8. G. Haller and I. Mezić, "Reduction of three-dimensional, volume-preserving flows with symmetry". *Nonlinearity*, **11**, 319-339 (1998).

9. I. Mezić, A. Leonard and S. Wiggins, "Regular and chaotic particle motion near a helical vortex filament". *Physica D*, **111**, 179-201 (1998).

10. A.N. Yannacopoulos, I. Mezić, G. Rowlands, and G.P. King, "Eulerian diagnostics for lagrangian chaos in three dimensional Navier-Stokes flows". *Physical Review E*, **57**, 482-490 (1998).

11. M.A. Bees, I. Mezić and J. McGlade, "Planktonic interactions and chaotic advection in Langmuir circulations". *Mathematics and Computers in Simulation*, Vol. **44**, 527-544 (1998).

12. A. Majumdar and I. Mezić, "Stability regimes of thin liquid films". *Microscale Thermophysical Engineering*, **2**, 203-213 (1998).

13. N. Malhotra, I. Mezić and S. Wiggins, "Patchiness: A new diagnostic for Lagrangian trajectory analysis in fluid flows". *Journal of Bifurcations and Chaos*, **8**, 1053-1094 (1998).

14. I. Mezić and S. Wiggins, "A method for visualization of invariant sets of dynamical systems based on ergodic partition". *Chaos*, **9**, 213-218 (1999).

15. I. Mezić and S. Wiggins, "Residence-time distributions for chaotic flows in pipes". *Chaos*, **9**, 173-182 (1999).

16. A. Banaszuk, H. A. Hauksson and I. Mezić, "A backstepping controller for a nonlinear partial differential equation model of compression system instabilities". *SIAM Journal on Control and Optimization*, **37**, 1503-1537 (1999).

17. A.C. Poje, G. Haller and I. Mezić, "The geometry and statistics of mixing in aperiodic flows". *Physics of Fluids*, **11**, 2963-2968 (1999).

18. D. D'Alessandro, M. Dahleh and I. Mezić, "Control of mixing in fluid flows: a maximum entropy approach". *IEEE Transactions on Automatic Control,* **44**, 1852-1864 (1999).

19. M. Ashhab, M.V. Salapaka, M. Dahleh and I Mezić, "Dynamical analysis and control of microcantilevers". *Automatica*, **35**, 1663-1670 (1999).

20. M. Ashhab, M.V. Salapaka, M. Dahleh and I Mezić, "Melnikov-based dynamical analysis of microcantilevers in scanning probe microscopy". *Journal of Nonlinear Dynamics*, **20**, 197-220 (1999).

21. A. Majumdar and I. Mezić, "Instability of ultra-thin water films and the mechanism of droplet formation on hydrophilic surfaces," *Journal of Heat Transfer -Transactions ASME*, **121**, 964-971 (1999).

22. M. Basso, L. Giarre, M. Dahleh, I. Mezić "Complex dynamics in a harmonically excited Lennard-Jones oscillator: Microcantilever-sample interaction in scanning probe microscopes". *Journal of Dynamical Systems-Transactions ASME*, **122**, 240-245 (2000).

23. G.O. Fountain, D.V. Khakhar, I. Mezic, and J.M. Ottino, "Chaotic mixing in a bounded three-dimensional flow". *Journal of Fluid Mechanics*, **417**, 265-301 (2000).

24. I. Mezić, "Chaotic advection in three-dimensional bounded Navier-Stokes flows". *Journal of Fluid Mechanics*, **431**, 347-370 (2001).

25. V. Salapaka, M. Dahleh and I Mezić, "On the dynamics of a harmonic oscillator undergoing impacts with a vibrating platform". *Journal of Nonlinear Dynamics*, **24**, 333-358 (2001).

26. I. Mezić, "Break-up of invariant surfaces in action-angle-angle maps and flows". *Physica D*, **154**, 51-67 (2001).

27. D. D'Alessandro, I. Mezić and M. Dahleh, "Statistical properties of controlled fluid flows with applications to control of mixing". *Systems and Control Letters*, **45,** 249-256 (2002).

28. I. Mezić and F. Sotiropoulos, "Ergodic Theory and Experimental Visualization of Chaos", *Physics of Fluids*, **14**, 2235-2243 (2002).

29. A. D. Stroock, S. K. W. Dertinger, A. Ajdari, I. Mezić, H. A. Stone, G. M. Whitesides, "Chaotic mixer for microchannels". *Science*, **295**, 647-651 (2002).

30. P. K. Newton and I. Mezić, "Non-equilibrium statistical mechanics for a vortex gas". *Journal of Turbulence*, **3**, Article number 052 (2002).

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33. G. Hagen and I. Mezić, "Spillover stabilization in finite-dimensional control and observer design for dissipative evolution equations". *SIAM Journal on Control and Optimization*, **42**, 746-768 (2003).

34. I. Mezić, "Controllability, integrability and ergodicity". *Lecture Notes in Control and Information Sciences*, **289**, 213-229 (2003).

35. S. Balasuriya, I. Mezić and C. K. R. T. Jones, "Weak finite-time Melnikov theory and 3D viscous perturbations of Euler flows". *Physica D*, **176**, 82-106 (2003).

36. T. H. Solomon and I. Mezić "Uniform, resonant chaotic mixing in fluid flows". *Nature*, **425**, 376-380 (2003).

37. G. Hagen I. Mezić and B. Bamieh "Distributed control design for parabolic evolution equations: Application to compressor stall control". *IEEE Transactions on Automatic Control*, **49**, 1247-1258 (2004).

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39. D. E. Chang, S. Loire and I. Mezić "Closed-form solutions in the electrical field analysis for dielectrophoretic and travelling wave inter-digitated electrode arrays". *Journal of Physics D-Applied Physics*, **36**, 3073-3078 (2004).

40. U. Vaidya and I. Mezić "Controllability for a class of area-preserving twist maps". *Physica D*, **189**, 234-246 (2004).

41. D. Vainchtein and I. Mezić "Optimal control of a co-rotating vortex pair: averaging and impulsive control". *Physica D*, **192**, 63-82 (2004).

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47. G. Mathew, I. Mezić and L. Petzold "A Multiscale Measure for Mixing", *Physica D*, **41**, 23-46 (2005).

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51. D. Vainchtein, A. I. Neishtadt and I. Mezić "Resonances and Mixing in Stokes Flows ". *Chaos*, **16**, Art. No. 043123 (2006).

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69. Y. Susuki, I. Mezić and T. Hikihara "Coherent Swing Instability of Power Grids" *Journal of Nonlinear Science*, 1-37, (2011)

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71. A. Hubenko, V. A. Fonoberov, G. Mathew, and I. Mezić, , "Multiscale Adaptive Search" *IEEE Transactions on Systems, Man and Cybernetics Part B-Cybernetics*, **41** , 1076-1087, (2011)

72. Yoshihiko Susuki, Igor Mezić, Takashi Hikihara "Coherent swing instability of interconnected power grids and a mechanism of cascading failure", *Control and Optimization Methods for Electric Smart Grids* . Book Chapter.

73. Maria Fonoberova, Vladimir A Fonoberov, Igor Mezić, Jadranka Mezić, P Jeffrey Brantingham,"Nonlinear dynamics of crime and violence in urban settings", *Journal of Artificial Societies and Social Simulation* **15** (2012).

74. Valentine, D. L., Mezić, I., Maćešić, S., Črnjarić-Žic, N., Ivić, S., Hogan, P. J., and Loire, S.. "Dynamic autoinoculation and the microbial ecology of a deep water hydrocarbon irruption." *Proceedings of the National Academy of Sciences*, **109**(50), 20286-20291 (2012).

75. Mezić, I. "Analysis of fluid flows via spectral properties of the Koopman operator." *Annual Review of Fluid Mechanics*, **45**, 357-378. (2013).

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79. Budišić, M., and Mezić, I. "Geometry of the ergodic quotient reveals coherent structures in flows." Physica D: Nonlinear Phenomena, 241(15), 1255-1269. (2012).

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95. Susuki, Yoshihiko Mezić, Igor "Nonlinear Koopman Modes and Power System Stability Assessment Without Models." IEEE Transactions on Power Systems, 54, 899-907. (2014).

96. A. Mauroy, B. Rhoads, J. Moehlis, I. Mezić "Global Isochrons and Phase Sensitivity of Bursting Neurons". SIAM Journal on Applied Dynamical Systems 13 (1), 306-338. (2014).

97. Mauroy, Alexandre, Mezić, Igor "Global stability analysis using the eigenfunctions of the Koopman operator", IEEE Trans Aut. Cont. (In Press) (2016).

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103. Levnajić, Zoran, Mezić, Igor "Ergodic theory and visualization. II. Fourier mesochronic plots visualize (quasi) periodic sets," Chaos: An Interdisciplinary Journal of Nonlinear Science, 25, 5, 53105. (2015).

104. Susuki, Yoshihiko; Mezić, Igor; Hoshino, Hikaru; Hikihara, Takashi "A Unified Definition of Collective Instabilities in Coupled Generator Networks," IFAC-PapersOnLine, 48, 18, 89-94. (2015).

105. Susuki, Yoshihiko; Mezić, Igor; Raak, Fredrik; Hikihara, Takashi "Applied Koopman operator theory for power systems technology". Nonlinear Theory and Its Applications, IEICE, 7(4), 430-459. (2016).

106. Thakur, Gunjan S, Mohr, Ryan; Mezić, Igor "Programmable Potentials: Approximate N-body potentials from coarse-level logic." Scientific reports 6 (2016).

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112. Ivić, Stefan, Bojan Crnković, and Igor Mezić. "Ergodicity-Based Cooperative Multiagent Area Coverage via a Potential Field." IEEE transactions on cybernetics (2017).

113. Hassan Aref, John R. Blake, Marko Budišić, Silvana S.?S. Cardoso, Julyan H.?E. Cartwright, Herman J.?H. Clercx, Kamal El Omari, Ulrike Feudel, Ramin Golestanian, Emmanuelle Gouillart, GertJan F. van Heijst, Tatyana S. Krasnopolskaya, Yves Le Guer, Robert S. MacKay, Vyacheslav V. Meleshko, Guy Metcalfe, Igor Mezić, Alessandro P.?S. de Moura, Oreste Piro, Michel F.?M. Speetjens, Rob Sturman, Jean-Luc Thiffeault, and Idan Tuval Rev. Mod. Phys. 89, 025007.

Books:

- "Normally Hyperbolic Invariant Manifolds in Dynamical Systems" (with S. Wiggins and G. Haller) Springer-Verlag, New York (1994).
- "Control of Fluid Flow" (Editor, with P. Koumoutsakos) Springer-Verlag, New York (2006).
- "Analysis and Control of Mixing with an Application to Micro and Macro Flow Processes Edited by Luca Cortelezzi and Igor Mezić, Springer-Verlag, New York (2009).

Professional activities:

Conference/Workshop/minisymposium organizer:

- Co-Organizer, mini-symposium on "Advanced data-driven techniques and numerical methods in Koopman operator theory" at the SIAM conference on Applications of Dynamical Systems (Snowbird, UT, USA), 2017.
- Co-Organizer,special session on "Koopman operator techniques for decision and control" at CDC 2016 in Las Vegas, USA.
- Co-Organizer, Invited Session on Operator-Theoretic Approach to Analysis of Nonlinear Systems: Koopman and Perron-Frobenius Operators , CDC 2015, Osaka, Japan.
- Co-Organizer, Mathematisches Forschungsinstitut Oberwolfach; Workshop on Applied Koopmanism, February 2016.
- Funding Agency Panel, 2015 SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah 2015
- Mini-Symposium on Koopman Operator Techniques in Dynamical Systems: Theory and Practice, 2015 SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah 2015.
- Invited Session on Operator-Theoretic Approach to Analysis of Nonlinear Systems: Koopman and Perron-Frobenius Operators , CDC 2015, Osaka, Japan.
- Mathematisches Forschungsinstitut Oberwolfach; Workshop on Applied Koopmanism, February 2016.
- Minisymposium: "Koopman Methods in Dynamical Systems", at the SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah, (2013).
- Minisymposium: "Uncertainty Propagation in Large-scale Networked Dynamical Systems", at the SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah, (2007).
- Workshop: "Coupled Nonlinear Oscillators and Applications in Nanosystems", Santa Barbara, CA, (with T. Hikihara, Kyoto University) 2007.
- A semester program in Dynamical Systems, Spring 2007, Mathematical Sciences Research Institute, Berkeley, CA. (with C. K. R. T. Jones (University of North Carolina), L.-S. Young (Courant Institute), A. Stewart (Warwick University) and J. Mattingley (Duke University)).
- Summer School and Workshop Analysis and Control of Mixing with an Application to Micro and Macro Flow Processes Sponsored by Marie Curie Program - EUA4X, CISM, Udine, Italy (with L. Cortelezzi, McGill University) (2005).
- Minisymposium: "Control of Hamiltonian Systems", at the SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah (with J. Meiss (University of Colorado)), (2005).
- Invited Session: "Uncertainty Propagation - Theory and Tools", at the Conference on Decision and Control (with T. Kalmar-Nagy (United Technologies Research Center)), (2004).

- Pre-nominated session on Chaos in Fluid and Solid Mechanics, XXI International Congress of Theoretical and Applied Mechanics, Warsaw, Poland (session chair with G. Rega, Rome), (2004).
- Two Workshops on Uncertainty Analysis in the Design of Dynamical Systems, at CIMMS, Caltech and United Technologies Research Center (UTRC), Hartford, CT (with J. E. Marsden (Caltech), M. Myers (UTRC) and A. Banaszuk (UTRC)), (2003/2004).
- Minisymposium: "Transport by Chaotic Advection in Three Dimensional Flows and Maps", at the SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah (with J. Meiss (University of Colorado)), (2003).
- Minisymposium: "Dimensional Reduction for Nonlinear Systems" , at the SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah (with R. Kupferman (University of California, Berkeley)), (2003).
- The First International Symposium on Turbulence and Shear Flow Phenomena (Member of the Executive Committee) (1999).
- Workshop on Dynamical Systems and Statistical Mechanics Methods for Coherent Structures in Turbulent Flows (with M. Farge, ENS, Paris) (1997).

Editorial Boards and Panels:

- Physica D (2001-2011) Editor.
- Dynamics and Stability of Systems (2000-2002) Member of the Editorial Board.
- Journal of Applied Mechanics (2003-) Associate Editor.
- SIAM Journal on Control and Optimization (2005-2013) Associate Editor.
- ASCE Notes in Mechanics Book Series (2010-) Associate Editor.
- Nonlinear Theory and its Applications (2012-) Editor.
- Advisory Panel SIAM Activity Group on Dynamical Systems (2015-) Elected Member.

Invited colloquium presentations (since 1999):

- 1999 "A Large-scale Theory of Axial Compression System Dynamics", Institute for Fluid Mechanics, ETH Zurich.
- 1999 "A Large-scale Theory of Axial Compression System Dynamics", University of Illinois, Urbana-Champaign.
- 1999 "Three-Dimensional Chaotic Advection", Division of Engineering and Applied Sciences, Harvard University.
- 1999 "Chaotic Advection in Three-Dimensional, Bounded flows", Department of Mechanical Engineering, Massachusetts Institute of Technology.
- 2000 "Ergodic Theory and Control of Mixing", Laboratory for Information and Decision Systems, Massachusetts Institute of Technology.
- 2000 "Control of Mixing", Department of Mathematics, Boston University.

- 2000 “Ergodic Theory in Fluid Mechanics”, Isaac Newton Institute for Mathematical Sciences, Cambridge University.
- 2001 “A Large-scale Theory of Axial Compression System Dynamics”, Division of Applied Mathematics, Brown University.
- 2001 “Control of Mixing”, Center for Nonlinear Science, Georgia Institute of Technology.
- 2002 “Modeling of Complex Systems”, Center for Integrative Multiscale Modeling and Simulation (CIMMS), Caltech.
- 2002 “Comparison of Dynamical Systems Based on the Spectral Properties of the Koopman Operator”, Department of Mathematics, UC Berkeley.
- 2002 “Micromixing”, Department of Aerospace and Mechanical Engineering, University of Southern California.
- 2002 “Comparison of Dynamical Systems Based on the Spectral Properties of the Koopman Operator”, Center for Nonlinear Science, Georgia Institute of Technology.
- 2002 “Chaotic Advection in Three-Dimensional Flows: Geometry and Physics”, Applied Mathematics Department, Columbia University.
- 2002 “Chaotic Advection in Three-Dimensional Flows: Geometry and Physics”, Courant Institute for Mathematical Sciences, New York University.
- 2002 “Comparison of Dynamical Systems Based on the Spectral Properties of the Koopman Operator”, Program in Computational and Applied Mathematics, Princeton University.
- 2003 “Ergodic Theory and Control Theory”, IGERT (Interdisciplinary Seminars in Nonlinear Science) Research Colloquium, Northwestern University.
- 2003 “Control of Mixing and Application in Microfluidic Devices”, Computations in Science Seminar, University of Chicago.
- 2003 “Mixed Orthogonal Decomposition”, Statistical and Applied Mathematical Sciences Institute, North Carolina.
- 2003 “Control and Mixing of Bioparticles”, California Nanoscience Institute, University of California, Santa Barbara.
- 2003 “Ergodic Theory Methods for Controllability”, Institute for Pure and Applied Mathematics, University of California, Los Angeles.
- 2003 “Mixing and Control of Particles in Microchannels”, United Technologies Research Center, Hartford, Connecticut.
- 2003 “Nonlinear Dynamics of Atomic Force Microscopes”, VEECO Inc.
- 2004 “Control of Mixing and Application in Microfluidic Devices”, Mathematics Department, McMaster University.
- 2004 “Control of Mixing and Application in Microfluidic Devices”, Mechanical Engineering Department, Stanford University.
- 2004 “Uncertainty in Analysis & Design: a Dynamical Systems Perspective”, Center for Nonlinear Science, Georgia Institute of Technology Mixing and control of particles in microchannels, GALCIT, Caltech
- 2005 “Two topics in coupling probabilistic and dynamical systems approaches for complex systems”, National Center for Atmospheric Research
- 2005 “Spectral Theory for Nonlinear Dynamical Systems”, LIDS, MIT
- 2005 “Control of Mixing: Ergodic Theory and Biosensors ”, University of Illinois at Urbana-Champaign.

- 2005 “Spectral Theory for Nonlinear Dynamical Systems”, CIMMS, Caltech.
- 2006 “Spectral Theory for Nonlinear Dynamical Systems”, University of Southern California.
- 2006 “Utilizing Nominal Dynamics in Control: A Theory for Hamiltonian Systems and Nanoscale Applications”, Institut de Mathmatiques, Univ. Bordeaux.
- 2006 “Biomolecules as Nonlinear Oscillators: Life-Enabling Dynamics”, Kyoto University.
- 2006 “Biomolecules as Nonlinear Oscillators: Life-Enabling Dynamics, Tokyo University
- 2007 “Physical Structure, Graph Structure and Uncertainty in Complex Systems”, UCSB
- 2007 “Theory and Practice of Active Microfluidic Devices”, MIT
- 2007 “Theory and Practice of Active Microfluidic Devices”, Univeristy of Wisconsin, Madison
- 2007 “Characterization of mixing and hyperbolicity in flows”, Ecole Normale Superieure, Paris
- 2007 “Active, Universal Particle Micromanipulators: CPUs for Microfluidics”, LLNL, Livermore, CA
- 2007 “Physical Structure, Graph Structure and Uncertainty in Complex Systems”, LLNL, Livermore, CA
- 2007 “Physical Structure, Graph Structure and Uncertainty in Complex Systems”, Courant Institute of Mathematical Sciences, New York University, NY.
- 2007 “Modeling for Design of Energy Efficient Buildings”, LBNL, Berkeley, CA
- 2008 “Uncertainty Analysis in Dynamical Systems, Institute for Pure and Applied Mathematics, UCLA
- 2008 “ Prandtl-Batchelor Theory in 3D and Optimal Control of Fluid Mixing”, Symposium in Honor of Anthony Leonard, California Institute of Technology.
- 2008 “ Uncertainty Analysis in Dynamical Systems”, CCDC, UCSB
- 2009 “Uncertainty Analysis: a Dynamical Systems Approach, Mechanical and Aerospace Engineering, Princeton
- 2009 Uncertainty Analysis: a Dynamical Systems Approach”, Applied Mathematics, UCLA
- 2009 “Uncertainty Analysis: a Dynamical Systems Approach”, Applied Mathematics, Arizona State University.
- 2010 “Integrated, Energy Efficient Design and Operation of Building Systems”, Department of Building Services Engineering, The Hong Kong Polytechnic University.
- 2010 “Analysis of Large-Scale Interconnected Dynamical Systems”, Tsinghua University, China.
- 2010 “Uncertainty Analysis: a Dynamical Systems Approach”, Probability and Statistics, UCSB.
- 2010 “Energy Dynamics”, Mechanical and Civil Engineering, Caltech.
- 2011 “Smart Grid and Analysis of Large-Scale Interconnected Dynamical Systems”, Los Alamos National Laboratory, Los Alamos, NM.
- 2011 “Analysis of Large-Scale Interconnected Dynamical Systems”, Caltech.
- “Energy Dynamics and a New System Analysis Framework”, ETH Zurich.
- 2011 “Integrated, Energy Efficient Design and Operation of Building Systems”, Nanyang Technological University, Singapore.
- 2012 “Mixing in Fluids: Visualization, Mode Decomposition and Diagnostics”, Nanyang Technological University, Singapore.
- 2012 “A New Systems Analysis Framework”, Mechanical Engineering, MIT

- 2013 "Energy Management in Buildings and Grid using Koopman Operator Methods", Electrical Engineering, Kyoto University
- 2013 "Energy Management in Buildings and Grid using Koopman Operator Methods", Tokyo Institute of Technology
- 2013 "Smart Grid and Analysis of Large-Scale Interconnected Dynamical Systems", Electrical Engineering, UCLA.
- 2014"Energy Management in Buildings and Grid using Koopman Operator Methods", Mechanical Engineering, UC Riverside.
- 2015 "Analysis of Fluid Flows and Mixing via Spectral Properties of Koopman Operator" UCLA, Mechanical Aerospace Engineering.
- 2015 "Koopman (Composition) Mode Expansion in Theory and Practice" Cambridge University, UK Control Theory Seminar.
- 2015 "Oil Spill Dynamics" BP Institute, UK.
- 2015 "Analysis of Fluid Flows and Mixing via Spectral Properties of Koopman Operator" DAMPT, Cambridge University, UK.
- 2015 "Koopman Operator Methods: Theory and Applications", UTRC DMD/Koopman workshop, Hartford, CT.
- 2016 "Theory and Application of Koopman Operator Methods" Hughes Research Laboratories.
- 2016 "Strongly Coupled Oscillators: A Koopman-Theoretic Approach", Network Frontier Workshop, Northwestern University.
- 2016 "Koopman Operator Methods: Theory and Applications", Mathematisches Forschungsinstitut Oberwolfach, Germany, Workshop on Applied Koopmanism.
- 2016 "Koopman Operator Theory in Fluid Mechanics" Department of Mathematics, University of Wisconsin, Madison.
- 2016 "Koopman Operator Theory in Fluid Mechanics" AEM Seminar at University of Minnesota.
- 2017 "Spectral Properties of the Koopman Operator: Theory, Computation and Applications", Electrical Engineering and Computer Science, University of Michigan.
- 2017 "Koopman Operator Theory in Dynamical Systems, Fluid Mechanics and Beyond", University of Rijeka, Croatia.
- 2017 "Spectral Properties of the Koopman Operator: Theory and Computation", University of Zagreb, Croatia.

Selected conference presentations (since 1999):

- 1999 "Transport and Mixing in Three-Dimensional Perturbations of Two-Dimensional Flows", American Physical Society Meeting, New Orleans. (Contributed).
- 1999 "Chaotic Advection in Three-Dimensional, Bounded flows", NSF-KDI/IGPP Workshop, San Diego, CA. (Invited Speaker).
- 1999 "Chaotic Advection in Three-Dimensional, Bounded flows", Integrating integrability into mathematics and science: Conference in honor of V. Zakharov's 60th Birthday. University of Arizona. (Invited).
- 1999 "Control of Mixing", NSF Workshop on Control of Fluids, UCSD. (Invited Speaker).
- 1999 "Dynamics and Transport in 3-D, Volume Preserving Maps and Flows", SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah. (Contributed).

- 2000 "Instabilities in Rotating Flows With Body Forces: Turning Navier-Stokes into a Reaction-Diffusion Equation", American Physical Society Meeting, Washington DC. (Contributed).
- 2000 "Chaotic Advection in Bounded Navier-Stokes Flows", ICTAM 2000, Chicago. (Contributed).
- 2000 "Overview of Some Theoretical and Experimental Results on Modeling and Control of Shear Flows", Conference on Decision and Control, Sydney. (Contributed).
- 2000 "Comparison of Systems with Complex Behavior", Conference on Decision and Control, Sydney. (Contributed).
- 2001 "Control of Nonlocal Reaction-Diffusion Equations; Application to Control of Instabilities in Axial Compressors" , SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah. (Contributed).
- 2001 "Control of Mixing", SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah. (Contributed).
- 2001 "Controlled Group Translations and Controllability of Nonlinear Systems", NOLCOS 01, St. Petersburg, Russia. (Contributed).
- 2001 "An Extension of Prandtl-Batchelor Theory and Consequences for Chaotic Advection", American Physical Society Fluid Dynamics Meeting, San Diego, CA. (Contributed).
- 2002 "Ergodic Theory and Control Theory", Mohammed Dahleh Symposium, UCSB. (Invited Speaker).
- 2002 "Modeling and Numerical Analysis of Mixing in an Actively Controlled Micromixer", HEFAT01, South Africa. (Contributed).
- 2002 "Mixing in Three-Dimensional Flows", SIAM Annual Conference, Philadelphia, PA. (Invited).
- 2002 "Control of Fluid Particle Motion and (Anti)-KAM Theory", Workshop on Dynamical Systems Methods in Fluids, Mathematisches Forschungsinstitut Oberwolfach, Germany. (Invited Speaker).
- 2002 "Mixing, KAM, Anti-KAM and Controllability", AFOSR Contractors Meeting, Pasadena, CA. (Invited).
- 2002 "Mixing in Three-Dimensional Flows", Workshop on sediment transport, Monte Verita, Ascona, Switzerland. (Invited Speaker).
- 2002 "On Control of Vortex Dynamics", American Physical Society Fluid Dynamics Meeting, Dallas, Texas. (Contributed)
- 2003 "Mixed Orthogonal Decomposition", American Mathematical Society Meeting, Baltimore, MD. (Invited).
- 2003 "Control of Mixing and Application in Microfluidic Devices", Dynamics Days Europe, Palma de Mallorca, Spain. (Invited Plenary Speaker).
- 2003 "An Actively Controlled Micromixer: 3-D Theory", American Physical Society Fluid Dynamics Meeting, New Jersey. (Contributed).
- 2003 "A Multiscale Measure of Mixing and its Applications", Conference on Decision and Control, Maui, Hawaii. (Invited).
- 2003 "Uncertainty Analysis: a Dynamical Systems Approach", Workshop on Uncertainty Analysis, Pasadena, CA. (Contributed).
- 2004 "Uncertainty Analysis: a Dynamical Systems Approach, DARPA Workshop on Uncertainty Analysis, United Technologies Research Center, Hartford, CT. (Contributed)
- 2004 "Mathematical aspects of mixing theory and application in m icrofluidic mixing AIMS Dynamical Systems and Differential Equations Conference, Pomona, CA . (Invited).
- 2004 "Spectral properties of dynamical systems and model reduction AIMS Dynamical Systems and Differential Eq uations Conference, Pomona, CA. (Invited)

- 2004 “Nonlinear dynamics of multicomponenmt dynamical systems”, ICTAM, Warsaw, Poland. (Contributed).
- 2004 “High Efficiency Mixing in the Shear Superposition Micromixer” APS DFD Meeting, Seattle, Washington. (Contributed)
- 2004 “Mixing and control of particles in microchannels” NOLTA 2004, Fukuoka, Japan (2004).(Invited)
- 2004 “Collaborations with UTRC 1997-2004” Conference on Decision and Control (CDC). (Invited)
- 2004 “Coupled Nonlinear Dynamical Systems: Asymptotic Behavior and Uncertainty Propagation” Conference on Decision and Control (CDC) (2004). (Contributed)
- 2005 “Coupled Nonlinear Dynamical Systems: Asymptotic Behavior and Uncertainty Propagation” SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah . (Contributed).
- 2005 “Dynamics and Control of Macromolecules”, SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah (2005). (Contributed)
- 2005 ”Uncertain, High-Dimensional Dynamical Systems” Workshop on Geophysical Dynamics, IPAM, UCLA (2005). (Invited)
- 2005 “Utilizing Nominal Dynamics in Control: A Theory for Hamiltonian Systems and Nanoscale Applications” Plenary Lecture at the 2005 SIAM Control Theory Meeting, New Orleans. (Invited)
- 2006 “Complex Systems Architectures: Rules, Interfaces, Modules, Dynamics”, DARPA Microsystems Technology Office Complex Systems Architectures Workshop Arlington, VA. (Invited)
- 2006 “Biomolecules as Nonlinear Oscillators: Life-Enabling Dynamics”, Plenary Lecture at the Second International Conference on Dynamics,Vibration and Control, Beijing, China. (Invited)
- 2006 “Biomolecules as Nonlinear Oscillators: Life-Enabling Dynamics”, Keynote Lecture at the Nonlinear Dynamics of Nanosystems Workshop, TU-Chemnitz, Chemnitz, Germany (Invited)
- 2006 “Physical Structure, Graph Structure and Uncertainty in Complex Systems”, Keynote Lecture at the Mathematics in the Science of Complex Systems Workshop Warwick University, UK
- 2006 “Optimal Control of Fluid Mixing” American Physical Society Division of Fluid Dynamics Meeting, Tampa, Florida (Contributed)
- 2007 “Robust Decision Making: Agent-Based Models and Dynamical Systems”, Robust Decision Making Workshop, AFOSR, Arlington, Virginia (Invited)
- 2007 “Controllability, Integrability, Ergodicity”, Mathematical Sciences Research Institute, Berkeley, CA (Invited)
- 2007 “Active, Universal Particle Micromanipulators: CPUs for Microfluidics”, Lab-on-a-Chip World Congress, Edinburgh, Scotland (Invited)
- 2007 “Characterization of mixing and hyperbolicity in flows”, International Congress on Industrial and Applied Mathematics, Zurich, Switzerland.
- 2007 “Nonlinear Multiscale Dynamical Systems, NOLTA, Vancouver 2007
- 2008 “Optimal control of mixing, The Southern California Conference on the Mathematics of Fluids, USC, March 29-30, 2008 (Invited)
- 2008 “Uncertainty Analysis in Dynamical Systems, Institute for Pure and Applied Mathematics, UCLA.
- 2008 “Prandtl-Batchelor Theory and Optimal Control of Fluid Mixing”, Symposium in Honor of Anthony Leonard, California Institute of Technology. (Invited)
- 2008 “Theoretical tools for modeling of self-assembly”, 6th International Symposium on Bioscience and Nanotechnology, Toyo University, Japan. (Invited)

- 2009 "Analysis of Large-Scale Interconnected Dynamical Systems", SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah (2009). (Invited Plenary Lecture)
- 2009 "Adversarial Games and Dynamical Systems", AFOSR Workshop on Adversarial and Stochastic Elements In Autonomous Control, Arlington, VA, March 2009 (Invited)
- 2010 "Integrated, Energy-Efficient Design", International Workshop on Smart Energy Management , Kyoto, Japan. (Invited)
- 2010 "Mixing and Transport: Visualization, Norms, and Control", IMA Workshop on Transport and Mixing in Complex and Turbulent Flows, April 2010. (Invited)
- 2010 "Harmonic Analysis, Complex Systems and Mixing ", SIAM Minisymposium In Memory of Dennis Healy and His Scientific Vision, SIAM Annual Meeting, Pittsburgh, PA, July 2010. (Invited)
- 2011 "Koopman Operator and Mixing in Fluids: Visualization, Mode Decomposition and Diagnostics", Workshop on The Physics of Mixing, Leiden, Netherlands, January 2011. (Invited Keynote Lecture)
- 2011 "Analysis of Large-Scale Interconnected Dynamical Systems: the Status, the Needs and the Future", Workshop on Future Directions in Applied Mathematics, North Carolina State University, May 2011. (Invited)
- 2011 "From Differential Topology to Koopmanism", ICIAM, Vancouver, Canada, July 2011. (Invited)
- 2011 "Uncertainty: Some Conceptual Thoughts and a Good Sampling Method", USA/South America Symposium on Stochastic Modeling & Uncertainty Quantification Rio de Janeiro, Brazil, August 1 5, 2011. (Invited Keynote Lecture)
- 2012 "Analysis of Fluid Flows via Spectral Properties of Koopman Operator", APS DFD meeting, San Diego.
- 2013 "Koopman Operator Methods: An Overview", SIAM DS meeting, Snowbird, UT.
- 2013 "System-Level Tools for Whole Building Analyses", Intelligent Building Operations Workshop, University of Colorado Boulder.
- 2014 "Energy Management in Buildings and Grid using Koopman Operator Methods", UC Riverside.
- 2014 "Koopman Operator Methods and Control", Contol of PDE's, Paris (Invited Plenary Lecture).
- 2014 "On the relationship between Koopman Mode Decomposition and Dynamic Mode Decomposition." American Physical Society, Division of Fluid Dynamics Meeting, San Francisco.
- 2015 "Koopman Mode Expansion in Theory and Practice", SIAM Conference on Applications of Dynamical Systems.
- 2015 "On Applications of the Spectral Theory of the Koopman Operator in Dynamical Systems and Control Theory" Conference on Control and Decision, Osaka, Japan.
- 2016 "Koopman Operator Methods: Theory and Applications" Mathematisches Forschungsinstitut Oberwolfach; Workshop on Applied Koopmanism.
- 2016 "Spectral Expansions, A Schrdinger-Type Formalism and Observable Wavefunctions in Dynamical Systems", International Symposium on NOLTA, Yugawara, Japan.
- 2017 "Extensions of the Koopman Operator Theory", SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah.

Reviewing and refereeing activity:

Air Force Office of Scientific Research, ASME, Automatica, IEEE Transactions on Automatic Control, Journal of Applied Mechanics, Journal of Computational Physics, Chaos, Control Systems Technology, International Journal of Robust and Nonlinear Control, European Physical Journal B,

International Journal of Heat & Mass Transfer , Journal of Fluid Mechanics, Journal of Nonlinear Science, Journal of Physical Oceanography, Journal of Physics A, Mathematical Reviews, Nature, Physica D, Physical Review E, Physical Review Letters, Physics Letters A, Physics of Fluids, The Physical Review, Journal of Micromechanics and Microengineering, Lab on a Chip, Springer-Verlag, United Technologies Research Center, National Institute of Health, National Science Foundation.

Consulting activity:

Propulsion Research Institute (1996-1998), Honda R & D (2000-2002), Combustion Research and Flow Technology (2000-2001), Guidant (2002-2003), United Technologies Research Center (1998-2013), Codman (Johnson and Johnson) (2002-2003), Prevention Research Institute (2004-2007), Ford Motor Company (2005-2013), National Science Foundation (1995-), AFOSR (1996-), Electricite de France 2011-2012, Ecorithm 2009-2016, Aimdyn 2003-.

Other professional activities:

- 2016 Panelist Applied Dynamical Systems Panel, National Science Foundation.
- 2016 Member,Advisory Panel, Dynamical Systems Activity Group, Society for Industrial and Applied Mathematics.
- 2014 Participant ARPA-E Workshop: Reducing CAPEX for Energy-Efficient Building Controls, Washington, DC.
- 2012 Participant National Energy Efficiency Technology Roadmapping Summit, Portland, Oregon.
- 2011 Participant, Developing Dependable and Secure Automotive Cyber-Physical Systems from Components, Troy, Michigan
- 2011 Participant, A National Summit on Advancing Clean Energy Technologies, Washington DC
- 2009 Participant, AFOSR Workshop on Adversarial and Stochastic Elements In Autonomous Control
- 2009 Participant, Workshop on Complex Aerospace Systems, Organized by DARPA and NSF
- 2008 Member, discussant panel National Workshop on High Confidence Automotive Cyber-Physical Systems , Troy, Michigan
- 2008 Member, discussant panel NSF Workshop on Foundations for Complex Systems Research in the Physical Sciences and Engineering,
- 2008 Member, discussant panel, National Workshop on High Confidence Automotive Cyber-Physical Systems , Troy, Michigan
- 2007 Member, Organizing Committee SIAM Conference on Control and its Applications, San Francisco, CA
- 2007 Organizer (with T. Hikihara, Kyoto U. Coupled Nonlinear Oscillators and Applications in Nanosystems, UCSB

- 2006 Visiting Professor, Kyoto University , Japan.
- 2006 Visiting Professor, Institut de Mathmatiques, Univ. Bordeaux, France.
- 2005, Panelist, National Science Foundation panel on proposals in Dynamics (Engineering Directorate).
- 2005, Member, Panel of the Defense Sciences Research Council Workshop on Design Principles for Complex Biological Systems, Washington DC..
- 2004, Member, Program Committee, Division of Fluid Dynamics of the American Physical Society.
- 2004, Panelist, National Science Foundation panel on proposals in Applied Dynamical Systems (Mathematics Directorate).
- 2003, Member, *Institute for Collaborative Biotechnologies*, University of California, Santa Barbara.
- 2002, Panelist, *Panel on proposals in Control Theory (Engineering Directorate)*, National Science Foundation.
- 2002, Member, *California NanoSystems Institute*, University of California, Santa Barbara.
- 2001, Participant, *National Science Foundation Workshop on "Frontiers of Mathematics in Geosciences", Institute for Mathematics and its Applications*, University of Minnesota.
- 2000, Participant, *Programme on "Geometry and Topology of Fluid Flows"*, Isaac Newton Institute for Mathematical Sciences (Cambridge, UK).
- 2000, Participant, *Meeting of the "Future Directions in Control and Dynamical Systems" panel*, Washington DC.
- 1999 Participant, *Programme on "Turbulence"*, Isaac Newton Institute for Mathematical Sciences (Cambridge, UK).
- 1999 ERCOFTAC Visiting Professor, Institut fur Flüiddynamik, ETH Zürich.
- 1996 Participant, *Programme on "Mathematical Modelling of Plankton Population Dynamics"*, Isaac Newton Institute for Mathematical Sciences (Cambridge, UK).

Grants and industrial gifts:

- 1997-2000 NATO "Chaos and Mixing in 3-Dimensional Maps and Flows" $4,591 Co-Principal Investigator (Co-PI).
- 1997-2000 AFOSR "Dynamics and Control of Instabilities and Mixing in Complex Fluid Flows; Applications to Jet Engines", $151,083, Principal Investigator (PI).
- 1997-2000 ONR "Transport and Mixing in Three-dimensional Oceanographic Flows" $120,000, PI.
- 1998-2001 NSF "Mathematical Methods of Chaotic Advection in Three-Dimensional Fluid Flows" $75,000, PI.
- 1998-99 Honda Research Initiation Grant "Control of Mixing and Applications in Three-Dimensional Fluid Flows" $25,000, PI.

- 1998-99 Propulsion Research Institute, Industrial gift. $12,000, PI.
- 1999 Ford Motor Company, Industrial gift. $10,000, PI.
- 1999-2003 “Nonlinear Dynamics and Control from Microscale to Macroscale”, NSF CAREER $200,000, PI.
- 2000-03 AFOSR “Nonlinear Dynamics and Ergodic Theory Methods in Control of Fluid Flows: Theory and Applications” $380,000, PI.
- 2000- NSF ITR “Computational Infrastructure for Microfluidic Systems with Applications to Biotechnology” $2,900,000, Co-PI.
- 2000- Honda R&D Industrial gift. $40,000, PI.
- 2000- NSF IGERT “Development of a Graduate Education Program in Computational Science and Engineering with Emphasis on Multi-scale Problems in Fluids and Materials.” $2,900,000, (co-PI).
- 2004 Institute for Collaborative Biotechnologies, “Modeling of microfluidics processes for improved sensitivity and accuracy of bio/chemical sensing devices”. $50,000 (PI).
- 2003-2006 AFOSR “Nonlinear Dynamics and Ergodic Theory Methods in Control” $450,000 (PI).
- 2003-2004 DARPA seed funding for research on “Analytical systems engineering: methodology for design of complex systems subject to uncertainty”. $750,000, (In collaboration with the United Technologies Research Center).
- 2004-2007 NSF-NIRT, “Titanium-Based Biomolecular Manipulation Tools”, $1,000,000. (co-PI).
- 2005 -2008 NSF-DMS, “Design of attractors for enhanced sensitivity biosensing”, $310,000 (PI).
- 2006-2008 AFOSR “ Uncertainty Analysis and Control for Nonlinear, Multiscale, Interconnected Systems”, $532,796 (PI).
- 2006-2009 DARPA “Robust Uncertainty Management, $2,291,315 (PI).
- 2007-2010 ONR “Drifter Motion Planning for Optimal Surveillance of the Ocean, $561,145 (PI).
- 2008-2009 DARPA “Design of Microstructure for Shape-Adaptive and Reflectance-Adaptive Materials, $250,000 (PI).
- 2009-2013 AFOSR “Dynamical Systems Analysis of Complex Networks $1,454,839 (PI).
- 2009 Ford Motor Company, Industrial gift $30,000 (PI).
- 2009 Lawrence Berkely Laboratory (via DOE) “Real time Assessment and Visualization of Model-Based Energy Performance in High-Performance Buildings”. $50,000 (PI).
- 2008-2010 Lawrence Livermore National Laboratory, “Design of Dielectrophoresis-based Microfluidic Devices $145,000 (PI).
- 2009 Sandia National Laboratory, “Complexity Issues in Mathematical Modeling of Infrastructure System Models $50,000 (PI).
- 2010 Air Force Office of Scientific Research, “Inferring Structure and Forecasting Dynamics on Evolving Networks ”, $143,793 (PI).
- 2010-2012 “3-D Effects, Robustness and Uncertainty Issues in Drifter and Glider Motion Planning for Optimal Surveillance of the Ocean (DRIMPOS)”, $450,000 (PI).
- 2010-2015 Office of Naval Research “Dynamical Systems Theory and Lagrangian Data Assimilation in 4D Geophysical Fluid Dynamics”, $725,880 (PI).
- 2010-2013 AFOSR “Multi-Scale Uncertainty Propagation in Dynamical Systems”, $953,565 (co-PI).
- 2014-2017 “ONR Koopman Mode Decomposition and mixing in Fluid Flows PI” $179,753 (PI)

- 2011-2016 ARO "Dynamics of System of Systems and Applications to Net Zero Energy Facilities", $875,000 (PI).
- 2014-2019 ARO MURI "New Theoretical and Experimental Methods for Predicting Fundamental Mechanisms of Complex Chemical Process, 3,750,000. (co-PI).
- 2017- ARO MURI "From Data-Driven Operator Theoretic Schemes to Prediction, Inference, and Control of Systems (From DDOTS to PICS)", 6,500,000 (PI).

Patents :

- Systems and methods for analyzing building operations sensor data, Mezic, Igor; Eisenhower, Bryan A; US Patent 9,043,163 (2015)
- Energy infrastructure sensor data rectification using regression models, Georgescu, Michael V; Mezic, Igor; US Patent 20,150,371,151 (2015)
- System and method for stability monitoring, analysis and control of electric power systems, Mezic, Igor; Susuki, Yoshihiko; US Patent 20,160,084,889 (2016)
- Dynamic equilibrium separation, concentration, and mixing apparatus and methods, Mezic; Igor , Bottausci; Frederic , Tuval; Idan, US Patent 8,182,669 (2012)

Students and postdoctoral fellows:
Thesis advisor:

1. George Mathew, (Researcher, United Technologies Research Center)
2. Domenico D'Alessandro, Ph. D. (Professor, Mathematics Department, Iowa State University).
3. Gregory Hagen, Ph. D. (Senior Researcher, United Technologies Research Center).
4. David Betz, Ph. D. (Researcher, Boeing Phantom Works).
5. Umesh Vaidya, Ph. D. (Professor, Electrical Engineering, Iowa State University).
6. Zoran Levnajić, M. S. (Professor, Novo Mesto, Slovenia).
7. Sophie Loire, Ph. D. (Research Fellow, Ecorithm, Inc.)
8. Marko Budišić, Ph. D. (Assistant Professor, Clarkson)
9. Bryan Eisenhower, Ph. D. (Associate Director, Center for Energy Efficient Design, University of California, Santa Barbara)
10. Ryan Mohr, Ph. D. (Senior Researcher, Aimdyn, Inc.)
11. Gunjan Thakur, Ph. D. (Research Scientist, Harvard)
12. George Gilmore, M. S. (Vice-President, Co-Founder of Mekube);
13. Blane Rhoads, Ph. D. (Intel Research)
14. Michael Georgescu, Ph. D. (Director of Research, Ecorithm)

Postdoctoral fellows and research scholars:

1. Emir Yasun 2016-
2. Milan Korda, 2016-
3. Alexandre Mauroy, (Assistant Professor, University of Namur, Belgium)
4. Yoshihiko Susuki, (Associate Professor, Osaka Prefecture University, Japan)
5. Yueheng Lan, (Professor, Tsinghua University, Beijing, China)
6. Maud-Alix Mader 2008-2011
7. Alice Hubenko 2007-
8. George Mathew, 2006-2007, 2008-2010
9. Symeon Griveopoulos 2006-2009
10. Kaixia Zhang 1997-1998 (General Electric Research),

11. Dmitri Vainchtein (Harvard, UCSB) 2000-2005,
12. Dong-Eui Chang (UCSB) 2002-2003,
13. Frederic Bottausci (UCSB) 2002-2007.
14. Sophie Loire, (2009-)
15. Bryan Eisenhower, (2009-2012)
16. Paul Kauffmann (2010-2012)
17. Marin Sigurdson 2013-2015

Documents Considered by Igor Mezic, Ph.D.

In addition to my prior Declarations and supporting exhibits submitted in this case, the following documents were considered in the preparation of my final report:

Declaration of Hunter S. Lenihan, Ph.D. [Dkt. 131]

Declaration of Randall Bell, PhD, MAI [Dkt. 125]

Declaration of Steve Roberts [Dkt. 129]

Declaration of Wade Bryant [Dkt. 371, 371-1, 371-2]

Declaration of Michael J. Fichera [Dkt. 373, 389-3]

Declaration of Paul D. Boehm [Dkt. 370, 370-1, 389-1]

Rebuttal Declaration of Paul D. Boehm [Dkt. 235]

Transcript of November 2, 2017 Deposition of Paul Boehm

Transcript of November 7, 2017 Deposition of Michael Fichera

Plains' Memorandum in Support of Motion to Strike [Dkt. 390]

Plains' Opposition to Renewed Motion for Class Certification [Dkt. 368, 389]

NOAA Shoreline Assessment Manual, 4th Edition; PLTF-EXPT-RB-0002857-3010

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